ETO Thyristor: Enabling Technology For Low Cost Power Conditioning System

Principal Investigator: Prof Alex Q. Huang
Center for Power Electronics Systems, Virginia Tech

SNL Project Manager: Stan Atcitty
DOE Manager: Dr.Imre Gyuk

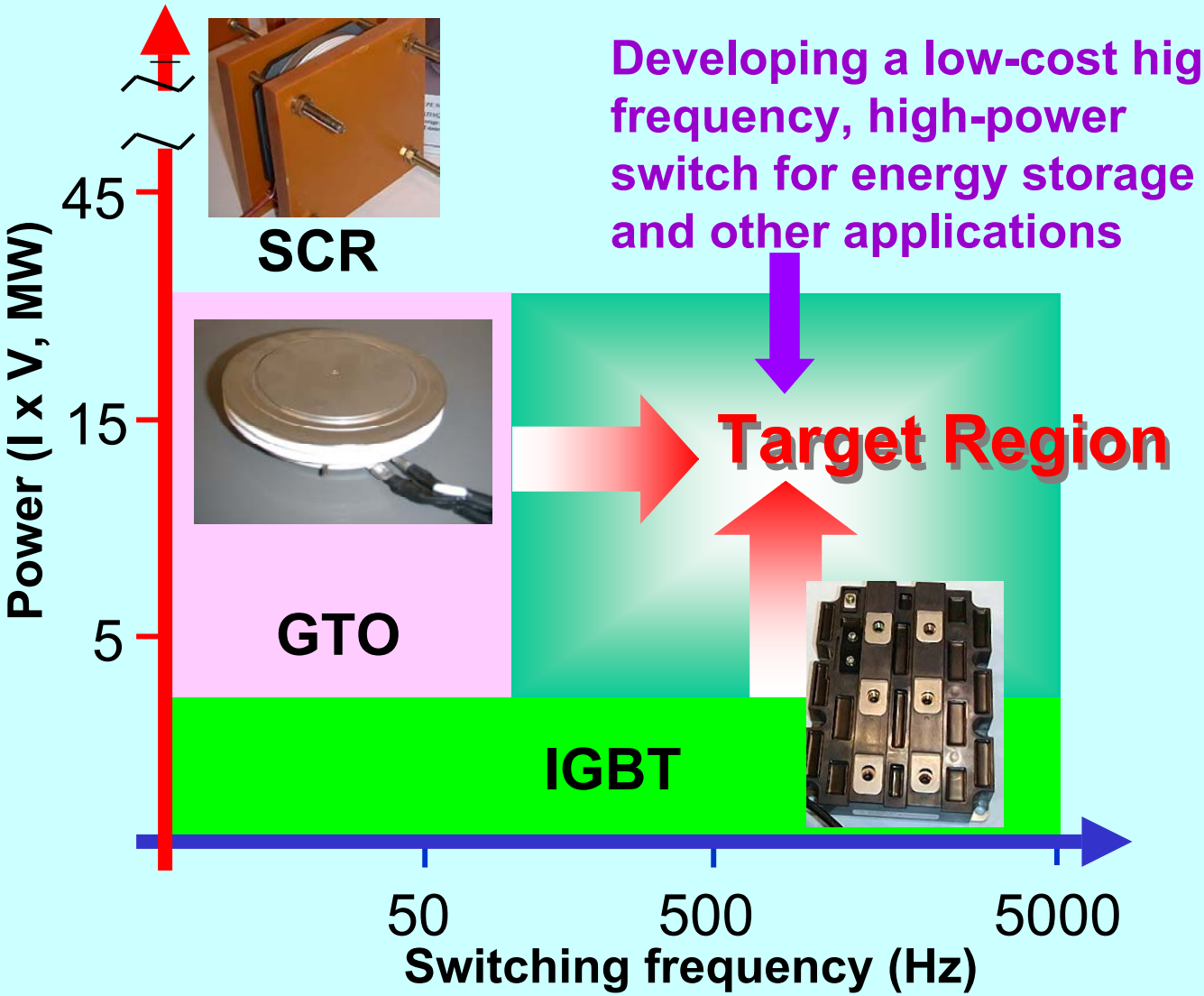
←Home

←Agenda

Presentation Outlines

- Project Objectives
- FY2002 Activities and Accomplishments
  - New generation ETO
  - The high-power pulse test of the ETO
  - Continuous high switching frequency test of the ETO
- Applications and Insertions of ETOs
- Planned Future Works

Project Objectives: Advanced High-Power Switch

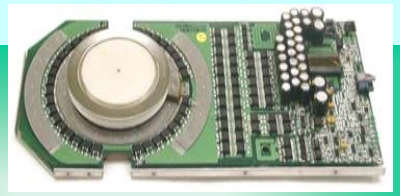


ETO: A New High Power Switch for PCS

- Low voltage MOSFETs integrated with high-voltage GTO
- Voltage control
- Using the anode current to provide the turn-off energy
- Unity turn-off gain enables fast switching speed
- Unity turn-off gain enables snubberless turn-off capability

SCR

GTO



IGBT

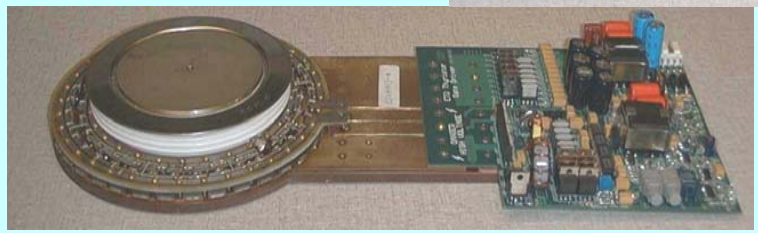
Emitter Turn-Off (ETO) Thyristor

Major ETO Development Roadmap

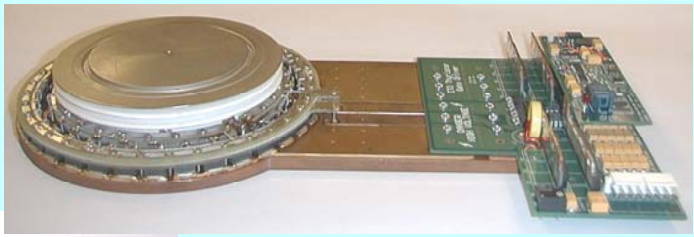
- ESSP supported three generations of development
- Gen-3 developed in FY2002
- Gen-4 will be developed for FY2003

Gen-3

Gen-2



Gen-1



Gen-0

1.0 kA to 4 kA
4.0 kV to 6 kV

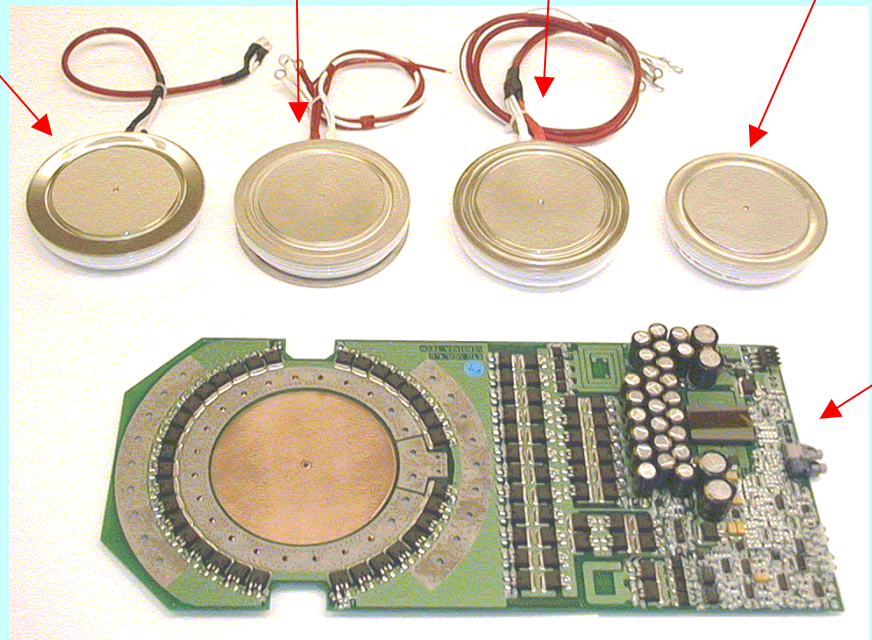
The ETO : low cost solution for high-power

ABB ETO
5SGT40L4502

Mitsubishi ETO
FG4000GX-90DA

Dynex ETO
DG858BW45

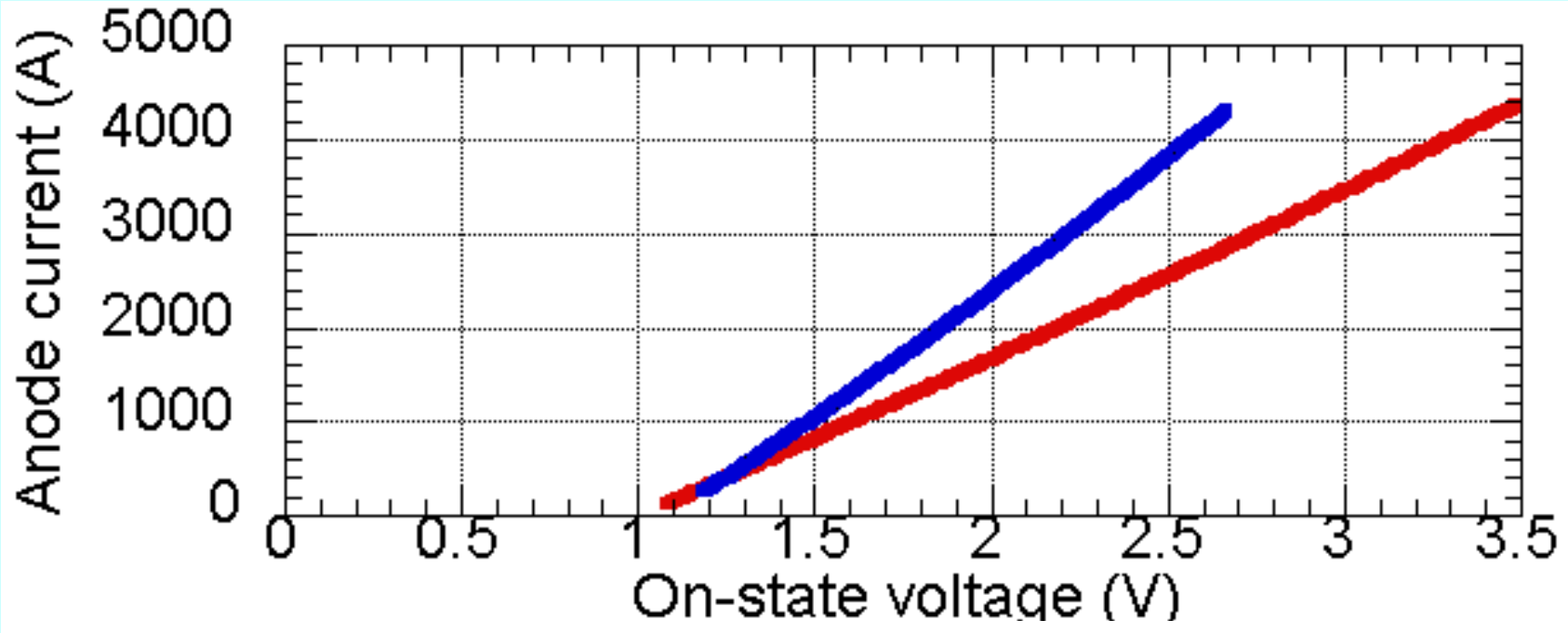
Toshiba GTO
SG4000 JX26



Universal
ETO driver

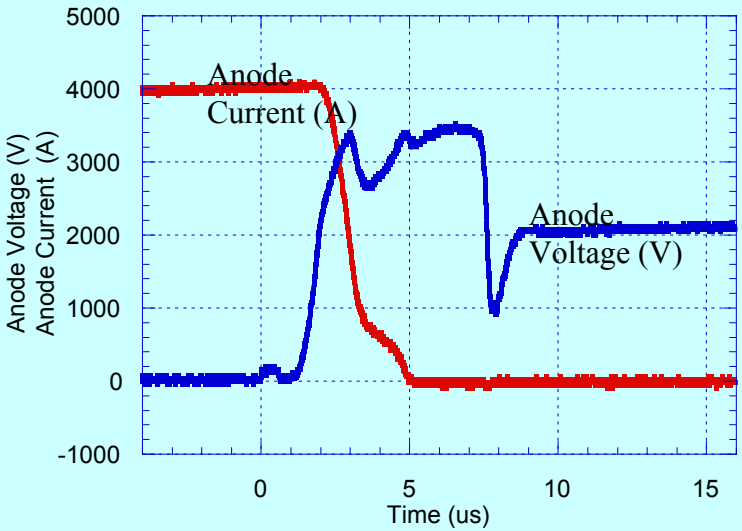
- The GTOs from different manufacturers can be used as the ETO's main switch to achieve the highest snubberless turn-off capability.
- The ETO can be optimized according to its application.

Significant ETO Characteristics



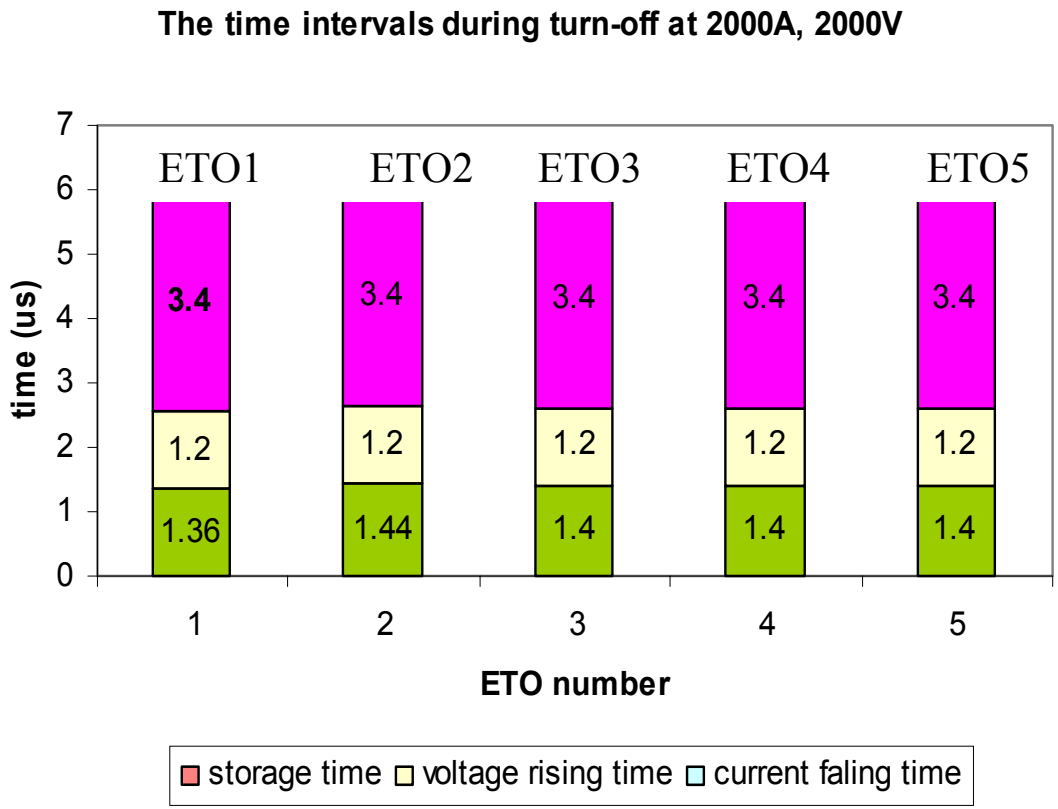
Positive temperature coefficient allows parallel operation

Significant ETO Characteristics

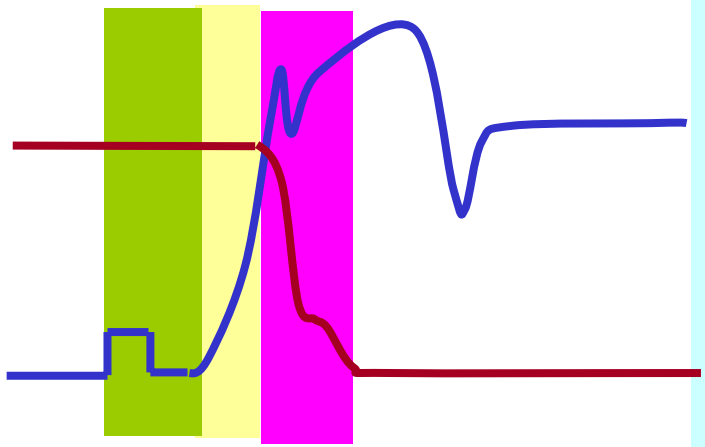


- **Snubberless turn-off capability allows elimination of snubbers hence simpler systems**

Significant ETO Characteristics

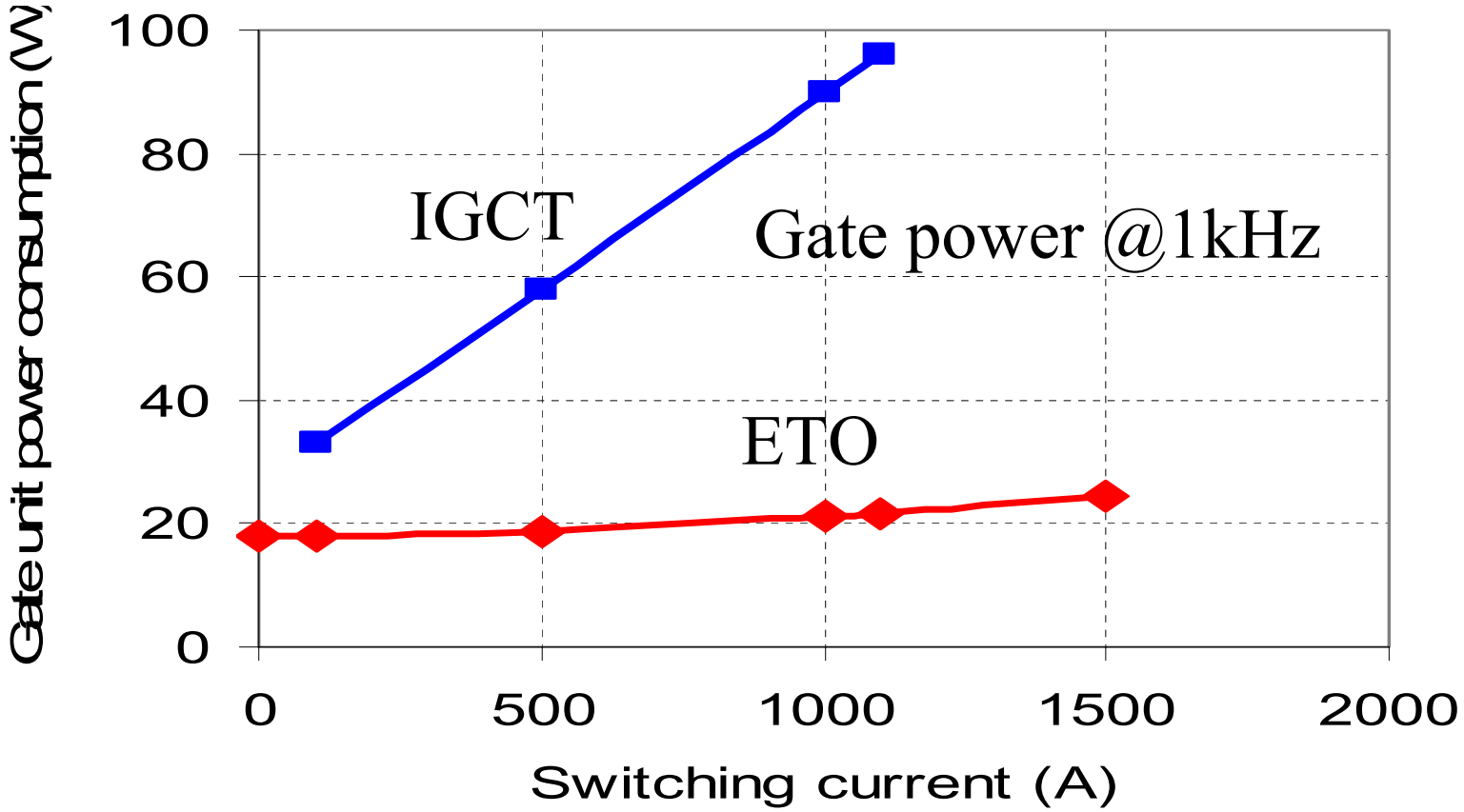


- Identical switching times allow series operation



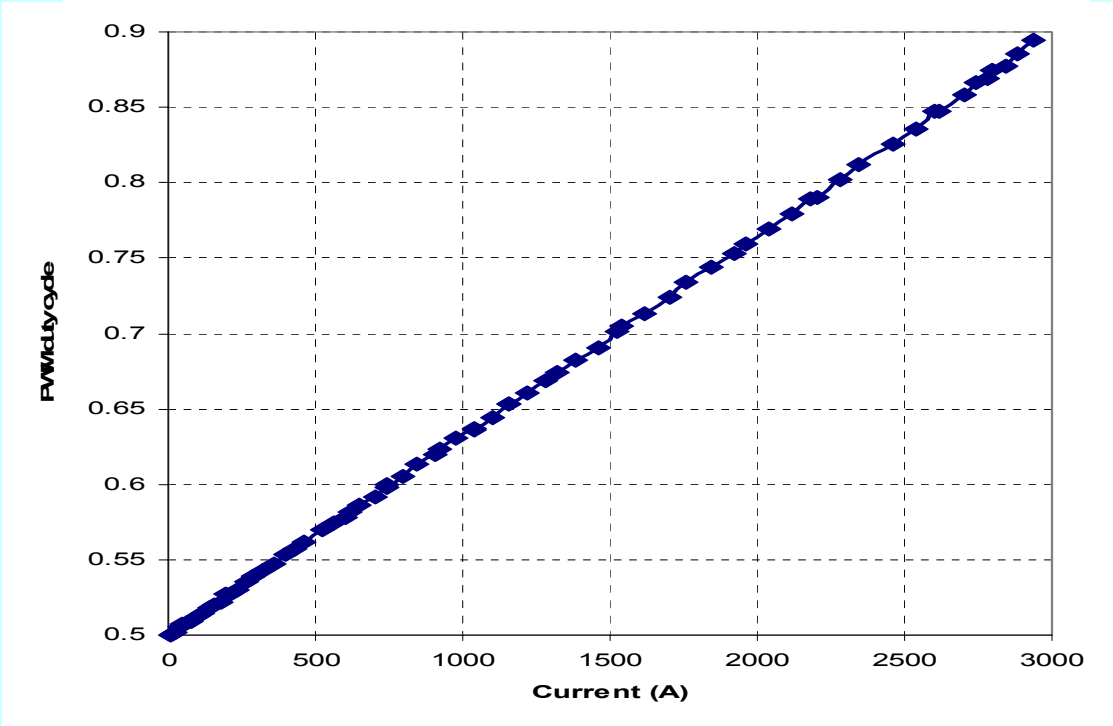
Significant ETO Characteristics

Very low gate control power enables high-frequency operation



Built-in Current Sensing Capability of the ETO

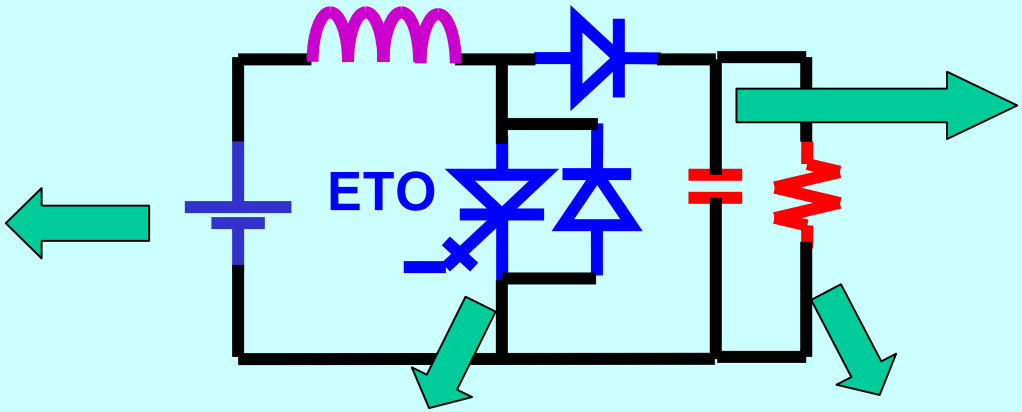
Measure current vs. output duty cycle



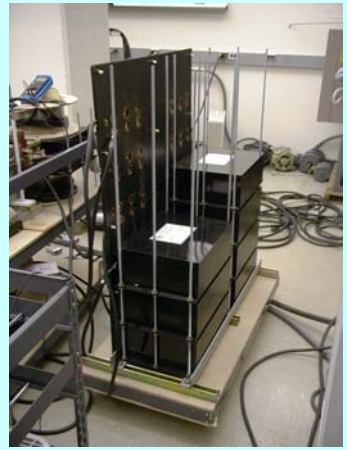
- Enables easy control and system protection

Continuous high switching frequency test of ETOs

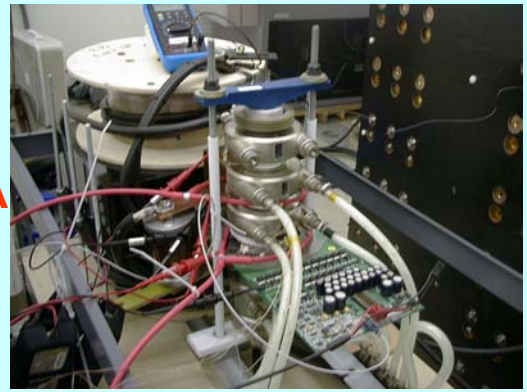
The 1000V/100A power supply

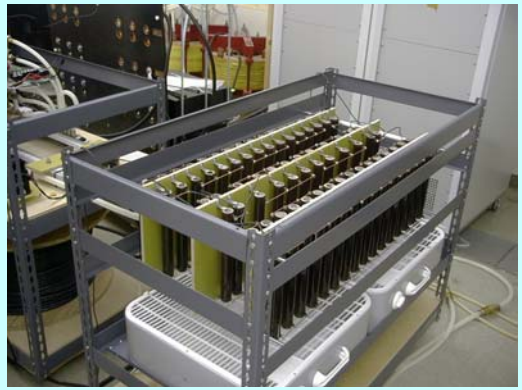


The cap filter



The 2000VDC, 1500A r.m.s, 1kHz ETO switch, Inductor, and diodes

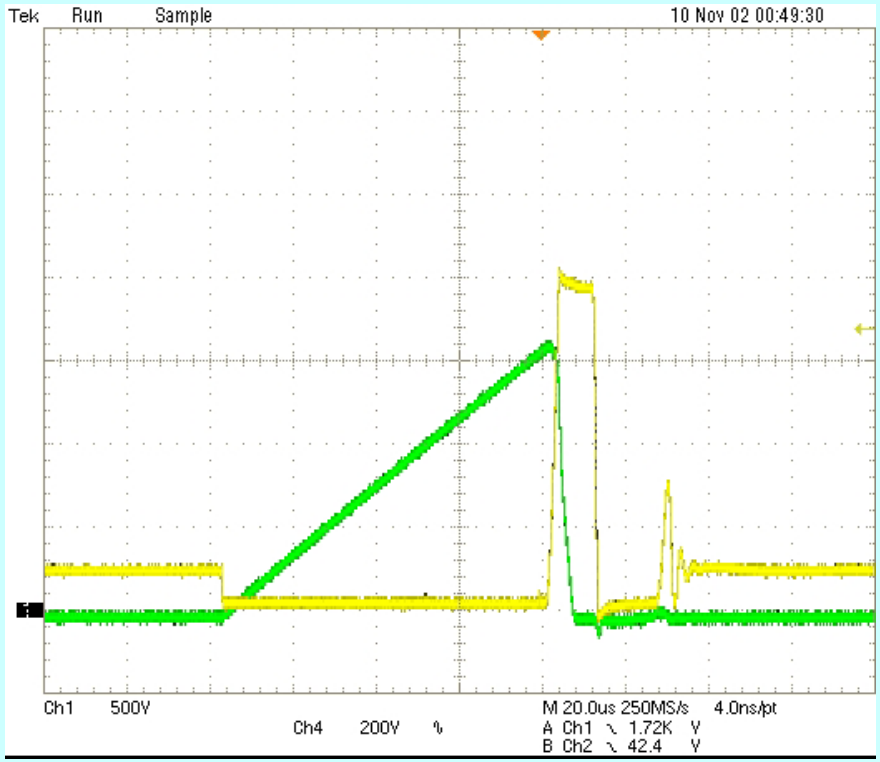




The 20kW resistor load

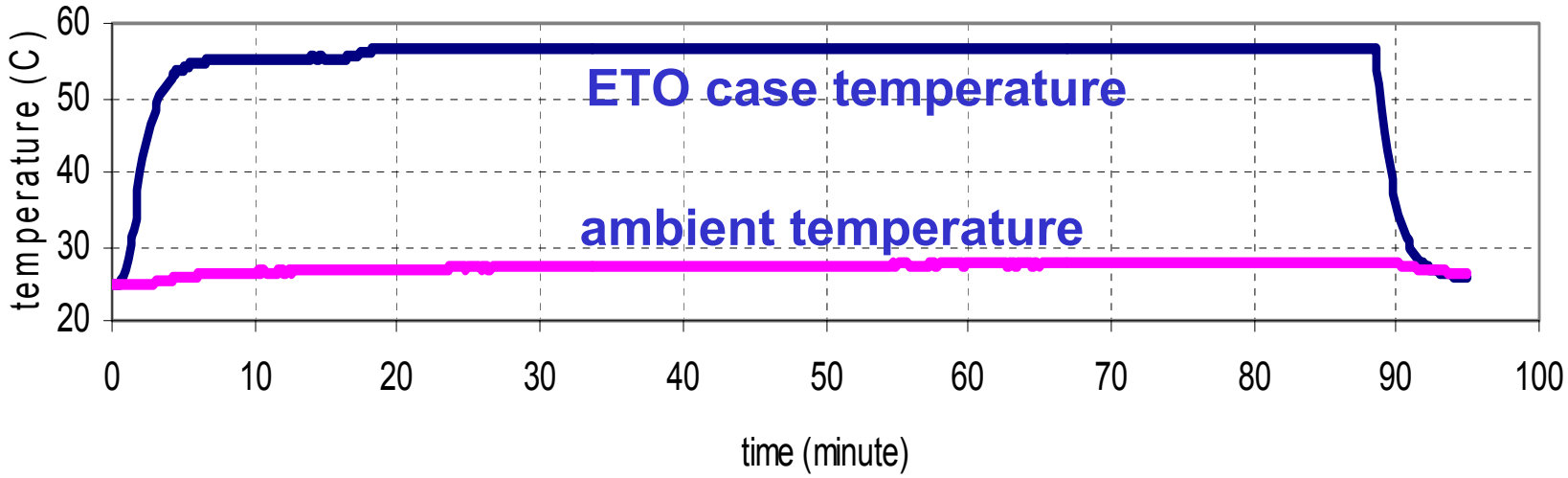
Objective: to test and evaluate the ETO's high switching frequency operation, thermal handling capability, control power consumption, and the reliability.

The high switching frequency test results



- Operation duration: continuous
- Switching frequency: 1 kHz
- Switching loss: 3.3 kW
- ETO peak junction temperature: >100 ^{O}C
- Snubberless turn-off current: 650A
- Snubberless turn-off bus voltage: 2000V

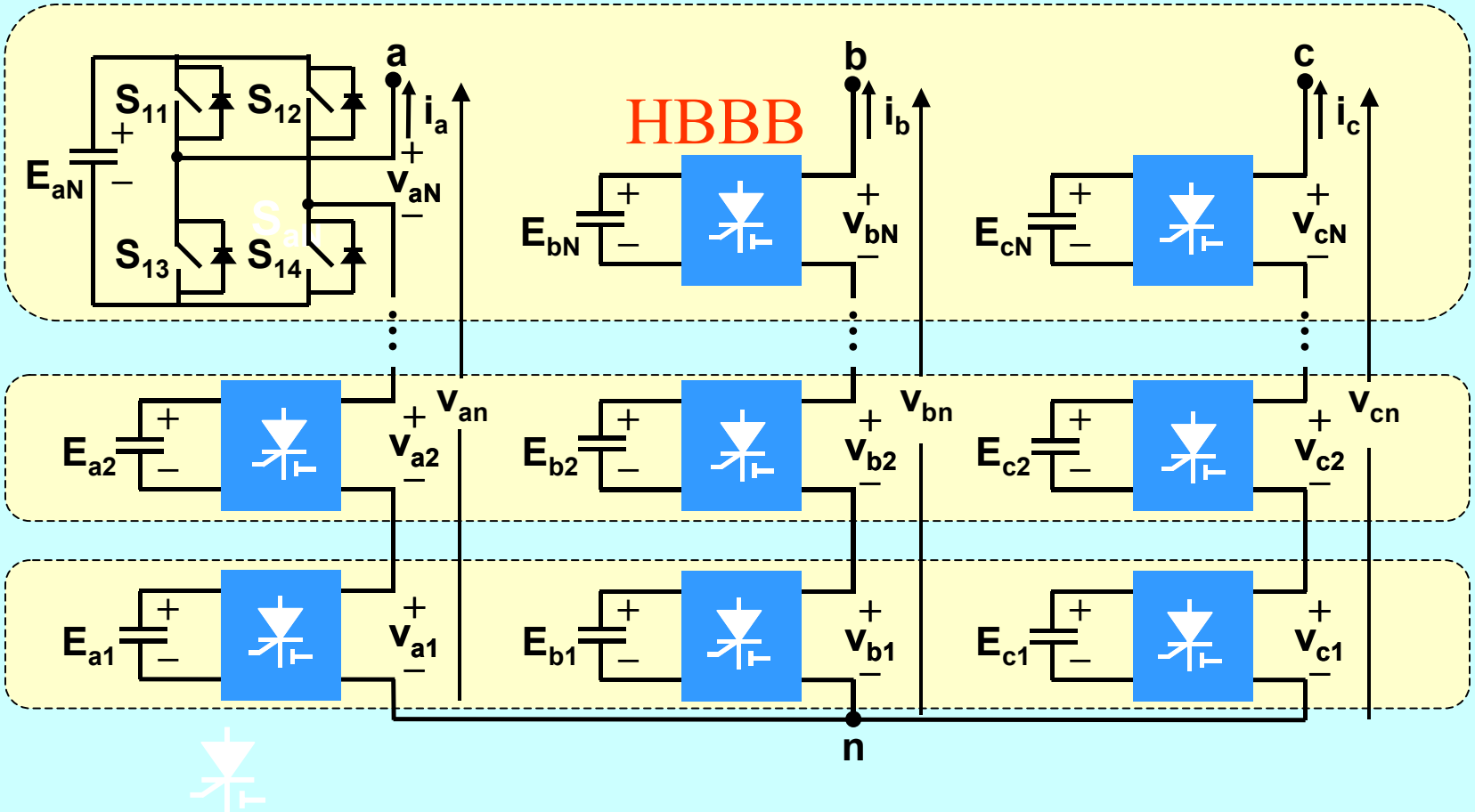
The thermal test results



Switching frequency: 1kHz, bus voltage : 2 kV, Switching current: 650A

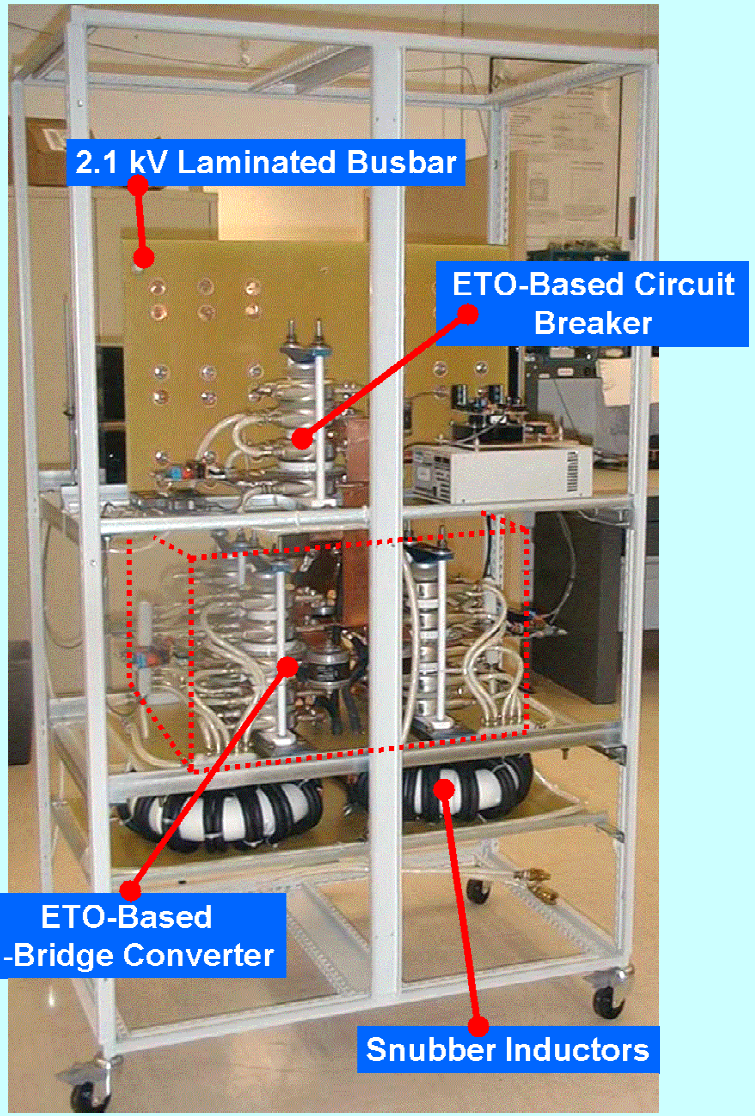
- **Reliable thermal handling characteristic of the ETO at high switching frequency was demonstrated.**

HBBB Enables Modular Multilevel Converter Design



- Modular and expandable topology for high voltage power systems,
- Considerably lower THD
- Fast dynamic (due to ETO and multilevel)

ETO-Based HBBB Prototype

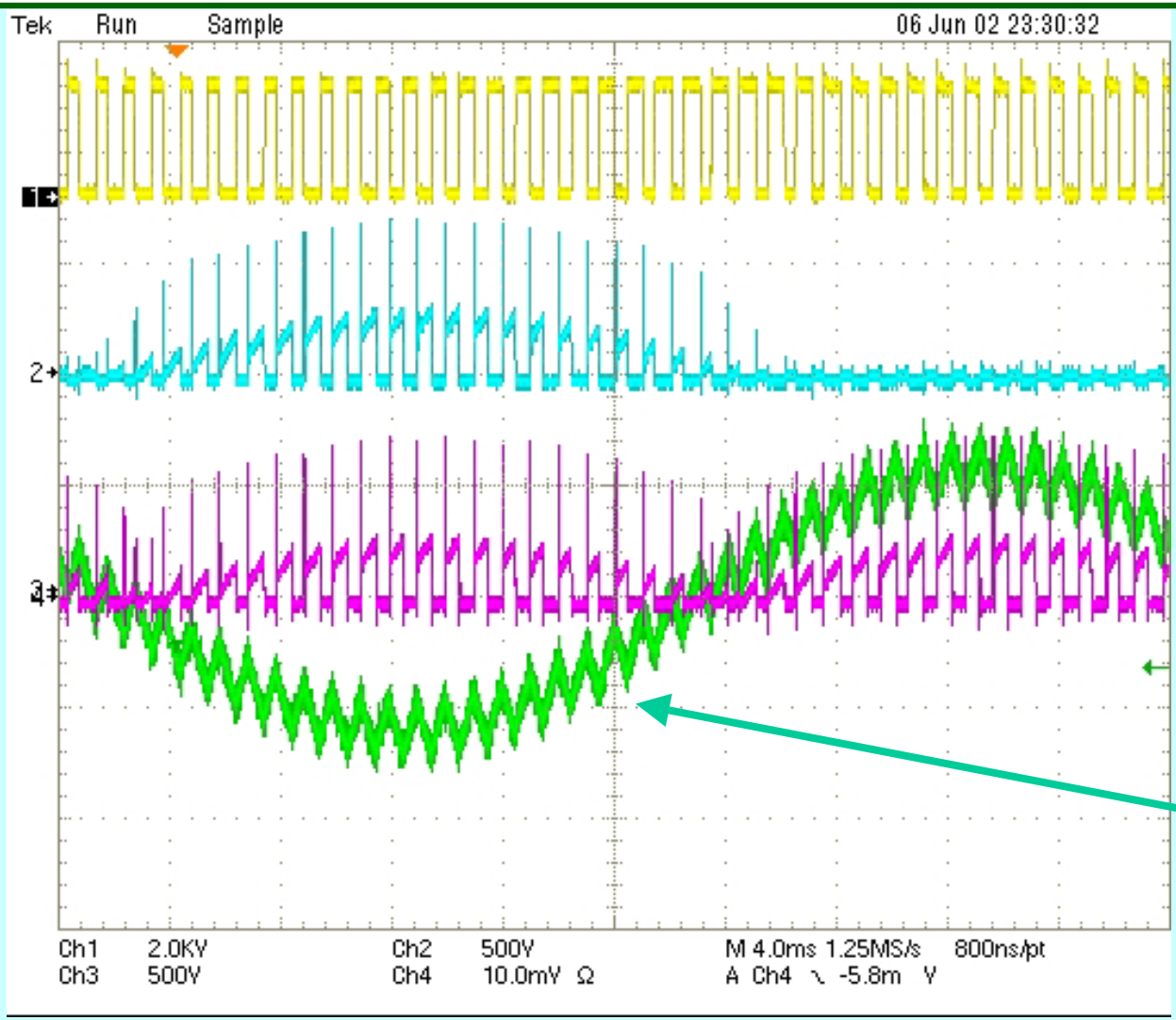


Specification :

- Main Devices : **4kA/4.5kV ETO**

  - di/dt Limitation : **200 A/μs**
- Bus Voltage : **2 ~ 2.5 kV**
  - Voltage Ripple : **10%**
- Output RMS Current : **1.25 kA**
- Switching Frequency : **Up to 2 kHz**
- Power Capacity : **1.5 MVA (3 MVA pulse)**
- Cooling System : **Water**

System Demonstration: ETO DSTATCOM

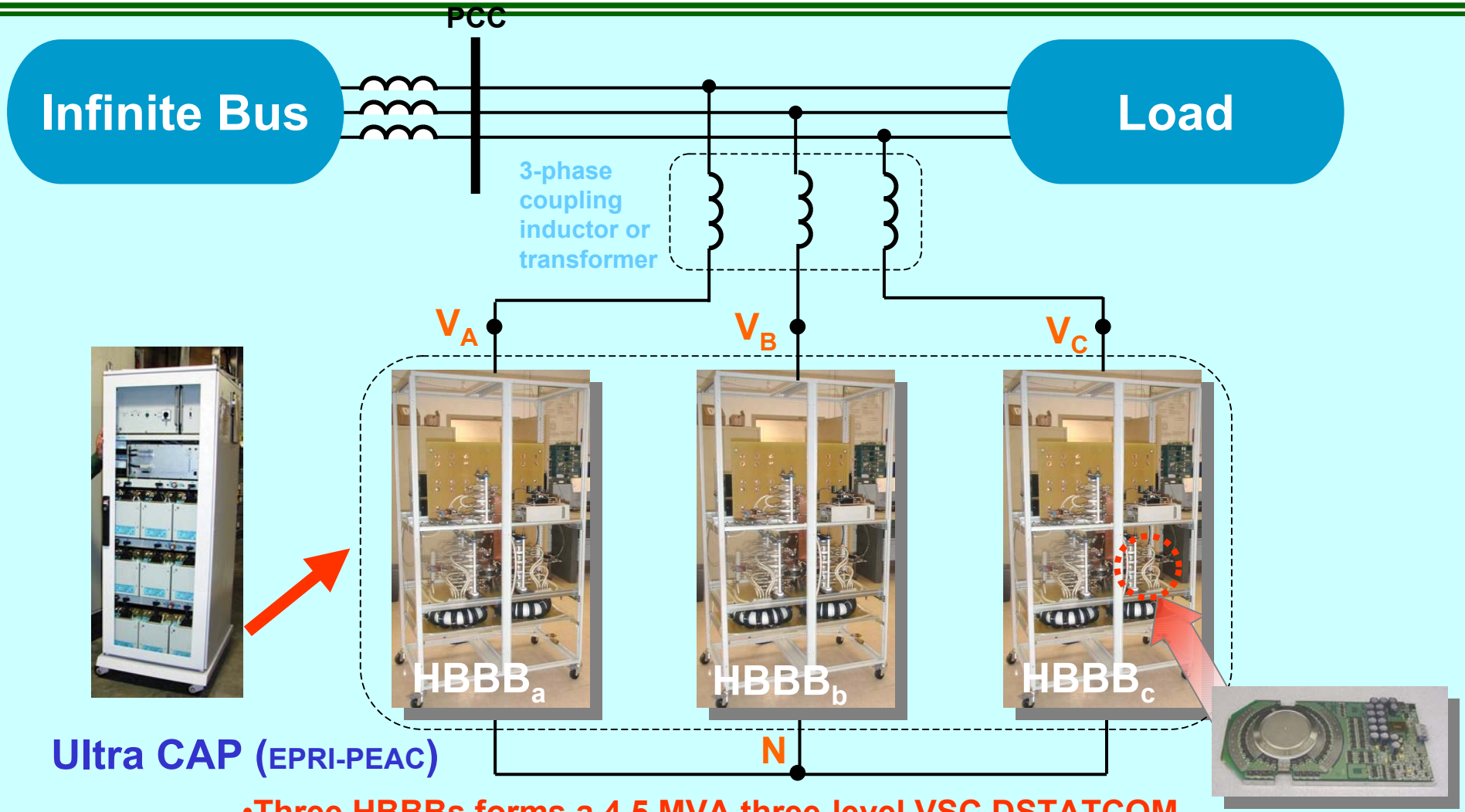


ETO voltage (2 kV/Div)

ETO current (1 kA/Div)

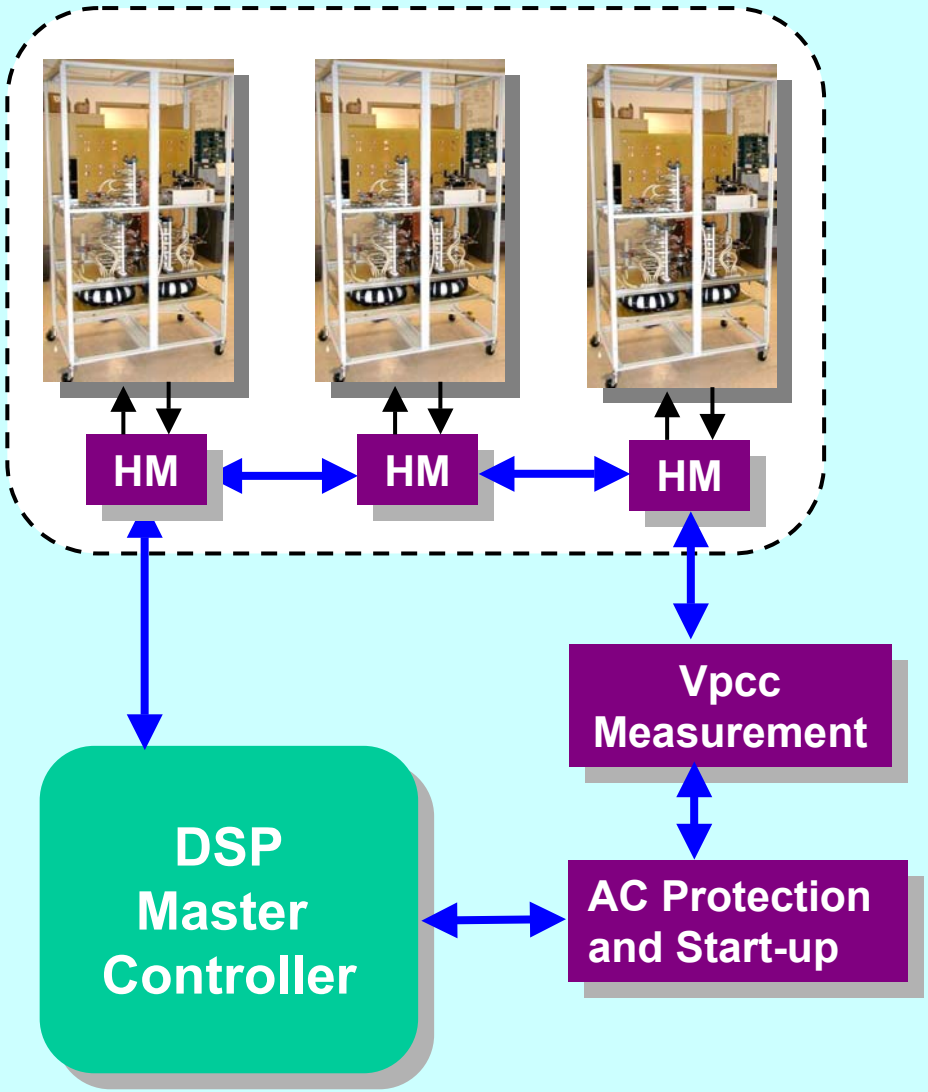
HBBB Output Current (500 A/Div)

Energy Storage System Demonstration Program



- Three HBBBs forms a 4.5 MVA three-level VSC DSTATCOM
- Can be used for real and reactive power support

Modular Digital Control Architecture



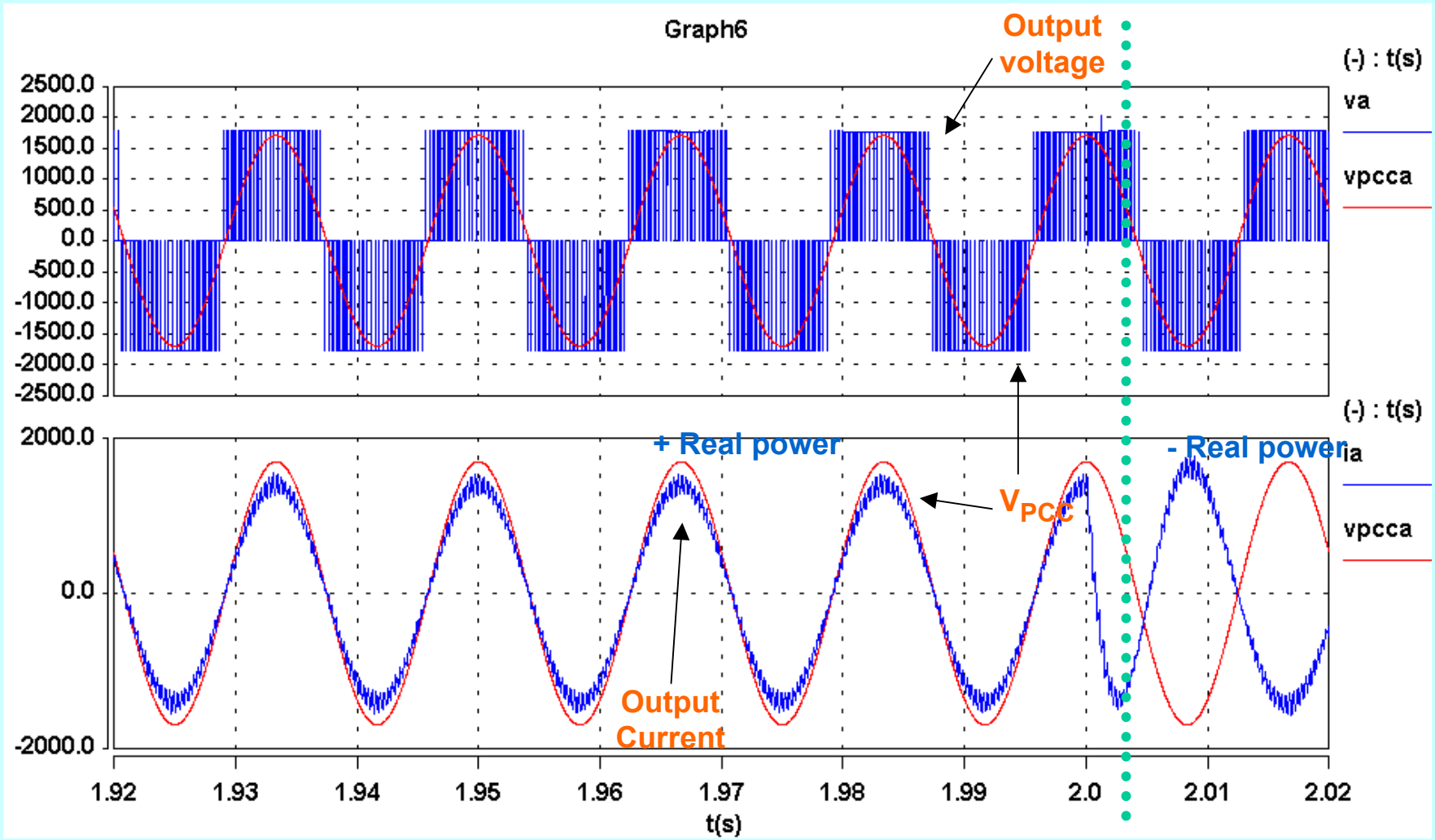
Key features of the control:

- HBBB provides modular power converter design
- Ring structure provides modular control design
- Allow easy expansion of # of levels and # of FACTS nodes
- All switching and measurement signals are transferred using one single optical fiber(+backup)
- Better performance, more reliability, and cost effective

Bi-directional Optical Signal

FPGA Local controller (under development)

Simulation Results of Real Power Compensation



Conclusions

Three key enabling technologies are developed at Virginia Tech

- Advanced switch technology (ETO)
  - ❖ 4000A snubberless turn-off capability
  - ❖ Low cost resulting from use of conventional GTO
  - ❖ Very low control power
  - ❖ Continuous & sustained operation at 1 kHz and Tj,max >125 ^{o}C is demonstrated
  - ❖ Gen-4 will be developed in FY2003
- Advanced modular converter technology (HBBB)
- Advanced modular digital controller technology

These technologies will enable low cost, advanced ESS implementation

DSTATCOM with energy storage are being developed

ETO commercialization and insertion are underway

Acknowledgment

• The ETO switch and system development are funded by DOE and managed by SNL through the ESSP, and by Tennessee Valley Authority .

• Supports from American Competitiveness Institute, ONR & NSWC are gratefully acknowledged.

↑Top

←Agenda